

Terahertz imaging for deterioration detection of East Asian artworks

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Abstract—Terahertz imaging was applied to examine East Asian artworks. The reflection image indicates a material map, and detached area is clearly observed as the distribution of air gaps. These results prove that terahertz imaging can be a new diagnosis tool of deterioration of artworks.

I. INTRODUCTION

MASTERPIECES of East Asian artworks, especially painting on paper, silk, or wood, have fragile surface comparing to typical western artworks with varnish layer on the surface, and therefore the analysis without contact is essential. The most important conservation process is reattaching parts which are detached from the preparation layer or from the support. Conservation materials, such as animal glue, are injected to the detached area from the visible crack line, and the amount and the direction rely on the conservator's experience. Detecting the detached area from the surface without contact is an ideal examination to make a conservation planning. THz time domain imaging using THz pulses can be used to estimate the material based on spectra, and to obtain internal structure of opaque materials, and has been applied to analysis of artworks [1]–[8]. This paper introduces examples of THz imaging results for conservation of East Asian artworks.

II. MATERIAL MAPPING

There is a rich history of the use of far-IR (THz) analysis in the study of semiconductors and inorganic materials in fundamental physics research. The absorption spectra of several inorganic pigments in the THz region, including most of the important pigments in historic paintings such as cinnabar (HgS) and orpiment (As₂S₃), were observed using the very first FT-THz system [9]–[11]. In the case of cultural heritage analysis, the measurement is usually performed in reflection mode, and thus it is important to obtain reflection spectra. Fig. 1 shows examples of reflection spectra of common pigments used in East Asian artworks. Lead white, minium, cinnabar has high reflection followed by calcite. The easiest material to have a map in artworks will be gold. Gold leaves under painted area were clearly observed in a tempera masterpiece [8]. Fig. 2 shows compares visible and THz images of a model made with gold leaf, calcite and azurite with animal glue. In this figure, the reflection level is described from black to white as minimum to maximum in the observed area. The reflection from the gold leaf is obviously strong, so that the existence of

gold leaf under paints can be easily recognised. Azurite has lower reflection, resulting in dark appearance.

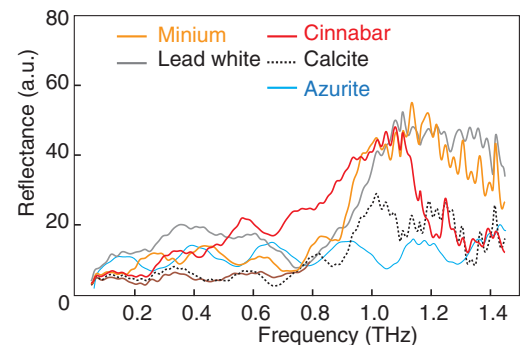


Fig. 1. Examples of THz spectra of pigments in reflection modes.

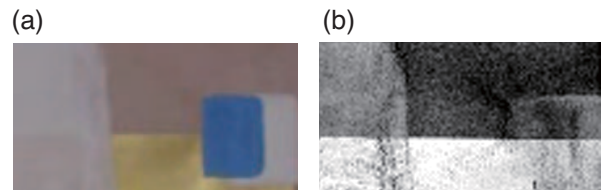


Fig. 2. Reflection imaging of a model paper paint. (a) visible image, (b) THz image.

III. IMAGING OF INTERNAL STRUCTURE

Fig. 3 shows a model of a painting and a comparison of observation methods. UV is useful for examining varnish, whereas IR can reveal the underdrawing. X-rays pass through most nonmetal materials. THz technology can be used to analyse the materials slightly below the layers of paint, such as preparation layers. According to conservators, information in the preparation layers is important in understanding works of art. The main advantage of using the THz region for conservation science is the capability of performing time domain imaging using THz pulses. This can provide a nondestructive cross-sectional image that helps conservators to understand the techniques used and to determine the layers in previous restorations. In particular, mapping (area information) of the layer of interest by extracting the pulse in the time domain for drawing the map in a multilayer structure cannot be performed by other existing methods.

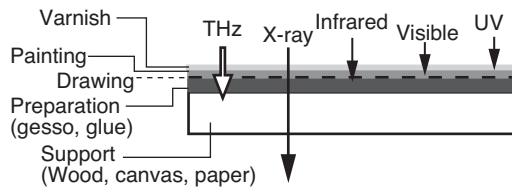


Fig. 3. Model of a typical painting and the use of various analysis methods.

We had the opportunity to analyse a painted pillar of a pagoda in Kiyomizu-dera Temple which is one of the most touristic place in Kyoto. As shown in Fig. 4, The reflection at the air gap is strong enough to be recognised under paints and preparation layers. In addition, non-invasive cross section images clearly show the gaps as well as cloth layer between the wood support (pillar) and the calcite preparation layer.

The mural painting of the Takamatsuzuka tomb is one of the most important artworks in Japanese history. We observed a part of the west wall, which has female figures. Fig. 5(b) shows a noninvasively obtained cross-sectional image along the dotted line in Fig. 5(a). The unclear reflection signals from the preparation layer made of calcite may be due to scattering in the porous structure of the deteriorated layer. Further investigation is desirable to evaluate the condition of the preparation layer; these results suggest that THz imaging is applicable for examining the condition of mural paintings.

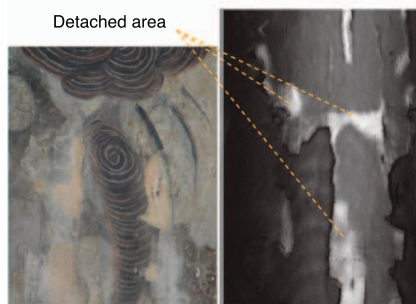


Fig. 4. THz observation of the surface of a wooden painted pillar.

IV. CONCLUSIONS

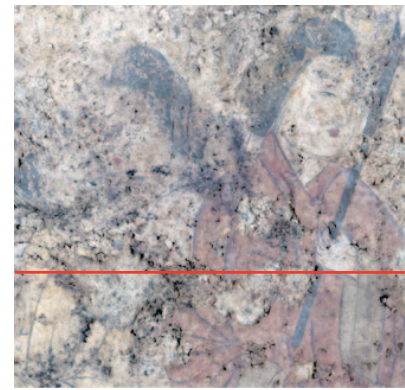
THz spectroscopy and imaging technique can provide useful information to art historians and conservators for investigating the history of an artwork, and are considered as a complementary technique to classical photographic analyses using frequency regions ranging from X-ray to the mid-IR.

ACKNOWLEDGEMENT

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Cross-section image along the red line

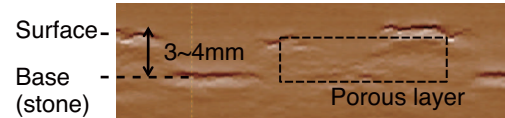


Fig. 5. Cross-sectional image of a mural painting of the Takamatsuzuka tomb.

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